Development a Statistical Measure for Empirical Mode Decomposition and Hilbert Spectral Analysis and its Applications to Oceanographic Data

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LONG-TERM GOALS

To establish a firm mathematical foundation for the Empirical Mode Decomposition (EMD) and the Hilbert Spectral Analysis Method.

OBJECTIVES

1. Define statistical metrics and evaluate performance of the Empirical Mode Decomposition and the Hilbert Spectral Analysis Method.

2. Apply the method to oceanographic data for interactions along the shelf break during the episodic events under strong wind and the ocean responses.

APPROACH

We propose to utilize the many adjustable parameters in the sifting processes to generate the Intrinsic Mode Functions in the EMD method, and measure their statistical variations. We can study the results from different parameter settings for the sifting, and assign weight for each of the sifted results. Our preliminary trials indicated that the applications of the different approaches showed small but detectable differences. Furthermore, we can also use the extrema to define the envelope function and conduct the sifting, and we can also invoke the intermittency test during the sifting as discussed by Huang et al. (1999). Each time, the IMF components are different. We would like to quantify this difference and to define the optimal criterion for implementing the sifting process.

WORK COMPLETED

Using the orthogonality index as a criterion, we have generated an ensemble of IMFs and Hilbert Spectra from a given data set. From that we have established a confidence limit. The result is submitted to the Royal Society of London for publication in the Proceedings.

RESULTS

The confidence limit in Fourier Spectral Analysis is established under the Ergodic assumption: The process has to be linear, stationary. We have defined a statistical measure in the form of a one-

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standard-deviation confidence limit for the Hilbert spectral representation as well as the corresponding marginal spectrum. This result is interesting by itself, for we have derived the confidence limit without invoking the Ergodic assumption. Rather, we have used various sifting criteria and obtained an ensemble of IMF sets, all from the same data. Furthermore, the confidence limit is still a function of time and frequency, if one chooses to average the results in the form of Hilbert spectra, whenever the number of the IMF components is not the same in different IMF sets. And the confidence limit can also be computed for the IMF components, if the number of the IMF components is the same in different sifting implementations. In the example presented here, the parameters chosen for the sifting is clearly important, but whatever criteria one chooses, the final results are reasonably close. They all reveal the underlying mechanisms quite well.

IMPACT/APPLICATIONS

As the Hilbert Spectral Analysis is not based on the convolution pairs from a priori basis function sets, the result is not limited by the uncertainty principle. Nevertheless, there is a limit on the prescision, because of the infinite many adaptive IMF basis sets the EMD can generated. Our present work has firmly established a confidence limit for this result, so that the EMD and Hilbert Spectral Analysis can be used with confidence from now on.

TRANSITIONS

The software have been widely used by many Universities, government laboratories. Naval Surface Warfare Center, Carderock Division sicentist has developed a new patent to measure the shock of structure based on HHT (Hilbert-Huang Transform is a short name for the comnination of EMD and Hilbert Spectral Analysis). Harvard Medical School is using it from some clinical research for identifying sleep apna. More than 70 Universities and Government Laboratories have signed special Space Act Agreement with NASA to use the software.

RELATED PROJECTS

The project is also supported by NASA Oceanic Program, and the Federal Highway Administration for Earthquake and bridge safety monitoring.

REFERENCES

Huang, N. E., Z. Shen, and R. S. Long, 1999: A New View of Nonlinear Water Waves – The Hilbert Spectrum, *Ann. Rev. Fluid Mech.*, **31**, 417-457.

Huang, N. E., H. H. Shih, Z. Shen, S. R. Long and K. L. Fan, 2000: The ages of large-amplitude coastal seiches on the Caribbean Coast of Puerto Rico. *J. Phys. Oceanogr.* , **30**, 2001-2012.

Huang, N. E., C. C. Chern, K. Huang, and L. Salvino, S. R. Long, and K. L. Fan, 2001: Spectral analysis of the Chi-Chi earthquake data : Station TUC129, Taiwan, September 21, 1999. *Bulletin American Seismological Society* 91, 1310-1338.

PUBLICATIONS

Huang, N. E. and others, 2003: On the establishment of a confidence limit for the empirical mode decomposition and Hilbert spectral analysis, Proc. Roy. Soc. Lond, Series A, (Under Revision).

PATENTS

Under related project, two patents were filed by NASA:

Speech analysis and acoustic signal analysis using HHT. (April 2002)

Instantaneous Frequency computation using HHT (October, 2002).